Applying Mixture Model to Studying Interlocking of Trajectory Groups in Adolescent Delinquency and Depression

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Abstract

From mixture model perspective, this paper explores the ‘interlocking’ of trajectory groups for adolescent depressive symptoms and delinquency. Types of delinquents have been studied in several studies; however, no study demonstrates the situation in non-western country. Besides, to our best knowledge, no study shows the types of depressive symptoms in adolescents. Current study plans to explore this literature gap and asks: does the co-occurrence of depressive and delinquency show for all types of developmental trajectories? Or it only shows up for specific trajectory groups.

Data are from a panel study in an urban area (Taipei) in Taiwan. The study has collected six-wave data and on its seventh data collection. Due to the missing of some measures, this paper uses first three waves and the fifth wave. After listwise deleting for missing data in the research variables, the final cases used in this study are 1021. There are 520 boys and 501 girls at their 13 in wave 1 and 17 in wave 5. We use Proc TRAJ (Jones et al., 2001), a SAS-based macro for analyzing group-based model.

The results show that there are three trajectory groups for boys’ delinquency and two groups for girls’. Both boys and girls have four depression trajectory groups. From the result of joint trajectory analysis, conditional probability helps us to understand the interlocking of delinquent and depression groups for boys and girls. When boys have specific depression trajectory membership, they show more clear patterns in delinquent trajectory groups, while the membership of delinquent trajectory groups does not help us to classify boys into depression trajectory groups. For girls, both memberships do not provide good classification for each other. Since we fit the comorbidity model, we don’t distinguish these two variables in their causal order. However, the inconsistency showed in boys provides some thinking about the co-occurrence of these two variables. Depression membership provides clear classification for boys’ delinquent trajectory groups. Researchers can’t leave the development of depression alone. We don’t find the same result for girls. This may be because there is small variation in girls’ delinquent trajectories. However, it is also possible that the patterns for girls show in the later years. This requests the continuous collection of the same measures of delinquency and depression over years.

Applying Mixture Model to Studying Interlocking of Trajectory Groups in Adolescent Delinquency and Depression

Findings from cross-sectional and longitudinal research have shown the co-occurrence of delinquent behaviors and depressive symptoms across adolescence and young adult. Under certain life course difficulty, such as family breakup, academic failure, and peer rejection, some kids are suffered and start to show delinquent behaviors and depressive symptoms. Research has shown the two problems have low to median correlations and the relationship is stronger concurrently than that across time (Overbeek et al., 2001). However, although the co-occurrence is well established in current literature, researchers are still puzzled by why and how these two problems are related.

Recent works from Overbeek et al. (2001) and Beyer & Loeber (2003) try to elucidate the causal relationships between these two problems. While Overbeek et al. (2001) use auto-regressive-cross-lagged model to test the relationships from variable centered perspective, Beyer & Loeber (2003) use growth curve model to detect the influence of depression on delinquency and vice versa from person centered perspective. Although both studies present complex methods and sound conclusion, the puzzle remains unsolved due to methodology limitations. As Beyer & Loeber (2003) state that the comorbidity occurs only in those having extreme externalizing problems, when using whole sample the relationships would tend to be weak and hard to be detected. The result from Patterson et al. (1992) also indicates that only small part of their deviant boys would experience the co-occurrence of delinquency and

depressive symptoms.

Current study try to explore this question using newly developed method—group-based model. From the finite mixture model tradition, Nagin (1999) develops his group-based model to distinguish developmental trajectories. Researchers can distinguish qualitatively different trajectory groups from multiple waves of data. Current study is going to use this statistical method to distinguish trajectory groups for adolescent delinquency and depressive symptoms. From the interlocking analysis, we hope to add some new understandings to the co-occurrence puzzle.

Literature Review

Developmental studies have outlined the developmental trajectories for delinquency and depression. Criminological studies show a one-peak trajectory of delinquent behavior over time in which the rate of delinquent behaviors reaches its peak during mid-adolescence and declines after entering adulthood (Blumstein et al., 1986). The studies of depression trajectories show that there is an increase during adolescence and young adulthood and there is also a group of people staying at certain depression level over time (Ge et al., 1994; Hankin, 1998). Therefore, findings from several studies observed a co-occurrence of these two problem behaviors during life course. Although the co-occurrence of these two variables has been well documented (Loeber & Keenan, 1994; Angold & Costello, 1993), not until recent decade, researchers start to explore the causal relationships between the two. In their summary

work, Overbeek et al. (2001) propose four possible explanations of the co-occurrence.

Stability hypothesis states that the two variables are related to nonspecific common causes. Therefore, the correlations between the two are spurious. We observe the stability of the two, but not the cross-lagged paths. Two hypotheses state the one-way cross-lagged paths. While acting out hypothesis proposes delinquency is an 'acting out' type of depression, failure hypothesis states that social rejection due to delinquent behaviors leads the failure experience and depressive moods. The final hypothesis proposes the mutual relationship between the two problem behaviors. Therefore, we would expect the reciprocal relationships between the two.

In their auto-regressive-cross-lagged models, they test these four hypotheses. Based upon model fit chi-square and model comparisons, their data support the stability hypothesis. However, although they use longitudinal data, the model they use is more like to test the relationships at variable level over time, not the individual changes. Research on human development turns their methods from variable-centered to person centered and therefore, auto-regressive-cross-lagged model gives way to growth curve models (Collins and Sayer, 2002; Curran, 2000; Duncan et al., 1999). Besides, in their stability model, they did not control for common risk factors. We are hard to know if the stability hypothesis is right without controlling for risk factors. Therefore, Overbeek et al's work still can't help us understand the causal relationships between delinquency and depression.

Beyer and Loeber (2003) present more sophisticated result regarding the causal relationships between delinquency and depression. In their growth curve model, they model the individual change of delinquency and depression. By incorporating delinquency as a predictor in depression model, depression as a predictor in

delinquent model, and common risk factors as controlling variables, their findings support the ‘acting out’ hypothesis in which negative emotion symptoms (i.e. depression moods) predict the rate of change of delinquent behaviors. Their growth curve models provide solid evidence for the causal relationships between delinquency and depression in two ways. First, they model the change at individual level (i.e. initial and rate of change factors). This provides more information regarding behavior trajectories over time other than general means at variable level. Second, they control wide-range risk factors for delinquency and depression. This makes their result powerful. However, there are limitations for their findings. The HLM approach can’t let them model delinquency and depression simultaneously. Therefore, we still need to caution about their result. Besides, Patterson et al. (1992) and Moffitt (1993) indicate that the delinquents are heterogeneous. Two types of delinquents are identified theoretically and they hypothesize that only those with high level and persistent delinquents would have depression moods at the same time. Therefore, research without taking the heterogeneity of delinquents only shows one part of the picture of the causal relationships.

In his series work (Nagin and Land, 1993; Land et al., 1996; Nagin, 1999; Jones et al., 2001), Nagin and his colleagues explore the delinquent trajectories using semi-parametric group-based model. By modeling the log-transformation of average offending rate with Poisson model, they present four offending trajectory groups in the Cambridge data and Pittsburg longitudinal study. In Nagin and Tremblay (2001), they demonstrate an interlocking method to incorporate the interlocking trajectory groups for two research interested variables. In the sense of conditional probabilities, researchers can present the relationships between two variables. Although this approach does not imply the causal inference between two variables, in the case of

our research question, this method does provide new information based on taking the population heterogeneity into account. Current study is going to present the trajectory groups for delinquency and depression and the interlocking of their trajectory groups from a non-western data set. By adding this new information, researchers can know the co-occurrence of delinquency and depression better.

The Development of Delinquency and Depression

Current study follows the work of Wu and Lee (2004). They use the first three waves of the data (described below) and fit the latent growth curve model to explain the causal relationship between adolescent delinquent behavior and depression. We extend their work in two ways. First, we include four waves in the analysis. This helps us model and test the quadratic shape of the developmental trajectories, which are more common in human behavior. Second, we use group-based model to see whether or not there are qualitatively different groups in these developmental trajectories. This helps us know better about the relationships between the two.

Current study we use Proc TRAJ, a SAS-based macro for analyzing group-based model. This program uses nonparametric maximum likelihood estimator to estimate the parameters. In addition to Poisson-based model, it can also deal with censored normal (and non-censored normal) and binomial data. The example showed below uses censored normal option to model the developmental trajectory groups of adolescent delinquency and depression. The model fitted in this analysis is:

$$y_{it}^{*j} = \beta_0^j + \beta_1^j Time_{it} + \beta_2^j Time_{it}^2 + \varepsilon_{it} \quad (6)$$

where y_{it}^{*j} is normal distribution and linked to y_{it} with

y_{it} =Minimum if y_{it}^{*j} < Minimum

y_{it} = y_{it}^{*j} if Minimum< y_{it}^{*j} < Maximum

y_{it} =Maximum if y_{it}^{*j} > Maximum

Further discussion about the use of censored normal option is in Nagin (1999), Nagin and Tremblay (1999) and Jones et al. (2001). Jones et al. (2001) provide details of how the program works and Proc TRAJ is used in several published articles (Nagin, 1999; Chung et al., 2002; Broidy et al., 2003). Therefore, this program has established reliability about the analysis of developmental trajectories. More information and examples about Proc TRAJ macro can be accessed on http://www.stat.cmu.edu/~bjones/traj.html.

Methods

Data and sample

Data are from a panel study in an urban area (Taipei) in Taiwan since 1996, named “The Etiology of Adolescent's Substance Abuse: A Social Learning Model.” This research was conducted by Chyi-in Wu, associate research fellow in Academia Sinica, Taiwan and was founded by National Health Research Institute in Taiwan for first three waves (DOH86-HR-621、DOH87-HR-621、DOH88-HR-621). Currently, this panel study is on its seventh wave data collection.

The population is 13-years teenagers in Taipei city in 1996. Since the enrollment rate in junior high school for this age group is close to 99.9%, it is appropriate to use all junior high school students in Taipei as a sampling frame. Using two-stage cluster sampling in twelve administrative areas of Taipei, researchers first randomly chose two or three junior high schools in each area and randomly selected one or two classes in each school. When the class was selected, all of the students in that class were included in the sample.

From September to November in 1996, the investigator sent trained interviewers to each selected class. Students filled out the questionnaire by themselves within 2 hours with interviewers' assistance if necessary. There were 1,434 junior high school students (around 13 years old) in wave one. Wave two and three were conducted by the same procedures during 1997 and 1999. There are some new students who transferred into sampled classes in wave 2 and wave 3. They were included in this investigation, too. Due to student's moving in or out of class, the third wave contained 1449 students (about 94.4% appearing across three waves). Because of the graduation from the original schools, in wave four researchers used phone interview to gather student's data from late 1999 to early 2000. Around 86% of students in original sample were contacted. In February 2001, researchers conducted the fifth wave investigation by interviewing students at their home. With trained interviewers' assistance, each student filled out the questionnaire by himself/herself at home. 1094 students were interviewed and about 80% of original sample participated in all five investigations. In this study, we dropped the fourth wave because it was conducted differently from the other waves. Thus, current study included wave one, two, three, and five. After listwise deleting for missing data in the research variables, the final cases used in this study are 1021. There are 520 boys and 501 girls.

The investigation collected data from students and their parents and teachers. Students, parents, and teachers reported their own information in these questionnaires. The delinquency and depression measures used in this study were from student questionnaire.

Measurement

We get our delinquency measures from student questionnaire. For our group-based model, we need to use the same delinquency measure across 4 waves. In wave 5, researchers used six items to measure adolescent self-reported delinquency. They asked respondents: “Did you have the following behavior during last year?” The items are: running away, skipping school, destroying things that do not belong to you, stealing, biting others, and speeding motorcycles. Respondents reported 1 as never and 5 as always. We summed the scores of six items and gained the means for each respondent. For wave one, two, and three, we used the same procedure to create the delinquency measures.

We used ‘The Symptom Checklist-90-Revised’ (SCL-90-R, Derogatis, 1983). There are 47 items in wave one to wave three student questionnaire. However, in wave 5, researchers reduced the scale to 15 items. Therefore, for consistency, we used these 15 items across four waves. The symptoms consisted of items such as depressed moods, feelings of helplessness and hopelessness, or feeling no interest in things. The Cronbach’s α of this reduced scale is 0.85 (wave 1), 0.83 (wave 2), 0.80 (wave 3), and 0.85 (wave 5) for boys. Girls’ reliability scores are 0.84 (wave 1), 0.83 (wave 2), 0.84 (wave 3), and 0.88 (wave 5). We can say this scale has good internal consistency. The respondents reported how much discomfort, on a scale from (1) not at all to (5)

extremely serious, he or she had experienced during the past week with regard to the listed items. We summed the 15 items and found the mean score for every respondent as his/her depression score.

Results

Descriptive statistics

Table 1 shows the correlations of delinquency and depression across waves. We can see for both boys and girls the stability of depressive symptoms is relatively high. The coefficients are around 0.4 or above, except for three cells. The long-term effect (i.e. the correlations between wave 1 and wave 5 depression) is low for boys and girls. This means there may be some change in their depression level across waves. In delinquent behavior, the patterns are different for boys and girls. For boys, earlier waves (one, two, and three) had low relationship with wave 5 measure, while the correlations between first three waves are around 0.3. However, we don't see strong stability for girls in delinquent behavior. When concerning the relationship between delinquency and depression, we observed the highest coefficients in wave 5 for boys and girls. Besides this, there is only moderate to weak relationship between these two variables across waves.

Zero-order correlations show some degree of change in these two variables aggregately over five years. However, we still don't know how individuals change in these two variables over time. As discussed above, for the next step, most researchers would use latent growth model, which gives us the shapes and variation of individual development over time to describe changes at individual level. From the mixture

model perspective, current study goes further to see whether or not there are qualitatively different groups in these individual changes.

Group-based model

In figure 1, we present the selected trajectories (200 cases) of delinquent behavior and depression for boys and girls. There are many different trajectory patterns in these figures. While some boys decrease from wave 1 to wave 2 and increase in the later waves, some show increase over time. For girls, the trajectories of delinquent behavior have simpler patterns than boys'. Among 200 cases, we only observe around 10 patterns in their developmental trajectories; however, there is still some level of variation in girls' trajectories. Compared with delinquent behavior, the trajectories of depression both for boys and girls show more patterns than those of delinquent behavior.

The various patterns of the trajectories in delinquent behavior and depression provide a good base for both latent growth curve analysis and group-based model. Table 4 presents the model selection process. According to D'Unger et al. (1998) Nagin (1999), we choose the smallest absolute value among these Bayesian Information Criteria (BICs). The formula of BIC is:

$$\begin{gathered} BIC = \log(L) - 0.5*\log(n)*(k) \\ \text{where} \\ L\text{: maximized likelihood value} \\ n\text{: sample size} \\ k\text{: number of parameters in the model} \end{gathered} \tag{7}$$

D'Unger et al. (1998) suggest a two-stage procedure to select the optimal model.

At the first stage, we fit the same shape of trajectory across groups as the baseline model. The BIC values in table 2 are from fitting outcome variables as a linear function of time. We can see for boys' delinquency, three-group model minimizes the BIC value. Two-group model for girls' delinquency fits data best and four-group model is the optimal model for boys' and girls' depression. Nagin and Land (1993) indicate the problem of comparing BICs between two models in group-based modeling, since k-1 groups are not necessarily the nested model of k groups solution. Following the suggestion of Kass and Raftery (1995) and Raftery (1995), if BIC difference between two models is greater than 6, there is strong evidence for the difference between two models. Therefore, table 2 shows strong evidence about our decision of number of groups.

At the second stage, we allow the function of time to be freed across groups. Table 3 and 4 show the best-fit models for this data set. When observing the observed and predicted trajectories in figure 2 to 5, we can find that they are very close. This is good evidence that our models fit the data well.

Delinquent behavior. Table 3 and figure 2 show the groups of boys' delinquent trajectories. There are around 39% of boys who never commit any delinquent behavior over five years. Therefore, we observe the zero intercept (non-significant) for this group. We call this group as 'Never' group. Half of boys are in the group called as 'Increase'. In this group, delinquent behavior shows curve linear relationship with time. We observe significant linear and quadratic term in table 3. These boys experience decrease in delinquent behavior from wave 1 to wave 3 and increase their delinquent behavior from wave 3 to wave 5. The developmental trajectory of this

group corresponds to Moffitt's 'adolescent-limited delinquents' (1993), who have few delinquent behaviors during their early adolescence, but show a jumping delinquency during their mid-adolescence (around age 16 and 17). It would be very interesting and theoretically important to see how this trajectory goes if we have later waves of data. At least, for current analysis, we find the left side of developmental trajectory about Moffitt's adolescent-limited delinquents. Compared with the first two groups, the last group of boys' delinquent behavior shows relatively high level of delinquency over time and there is also an increase in later waves. We observe significant intercept and slope in table 3. We call them as 'high rate' delinquents. This group corresponds to Moffitt's description of life-course-persistent delinquents in two ways. First, they show high rate of delinquency over time, around 3 times as 'Increase' group. Second, they account for around 10% of current sample. In Moffitt's theory (1997), she summarizes the existing literature and statistical reports and concludes that life-course-persistent delinquents account for around 5% to 10% in population. Our analysis confirms her conclusion.

Moffitt's theory and literature of criminal career are built upon male offenders. Only few studies investigate the developmental trajectories of female's delinquent behavior, not to mention the study about female delinquents in non-western countries. Figure 4 shows two groups of delinquent trajectories for girls. It is interesting to note that we observe half of them are never offenders and another half show similar pattern as 'Increase' group in boys' sample. Therefore, we name them as 'Never' and 'Increase' respectively. Table 6 shows that for 'Never' group they have significant intercept, but not significant slope (i.e. a flat line across waves). This means the initial level of 'Never' group is different from zero and constant over time; however, as presented in figure 4, the rate is very low. For 'Increase' group, we observe a

quadratic relationship between delinquent behavior and time. The U-shape indicates the low level of delinquency around second and third waves and an increase after that. We can treat this group as ‘adolescent-limited delinquents’ in Moffitt’s theory.

Depression. Figure 3 shows the developmental trajectory groups of boys’ depression. We identify four groups. We observe one flat group (non-significant slope) in table 3 with moderate degree of depression over five years. We name it as ‘Moderate-Constant’. Around 80% of boys consist of a group, which shows low initial rate with low and positive slope. This group can be called ‘Low-Increase’ group. Contrast to these two groups, we also observe two small groups of boys experiencing big changes across five years. The ‘Increase’ group has low initial level in wave 1, but increases almost 2 times as the initial level in wave 5. On the contrary, the ‘Decrease’ group shows high initial level in wave 1 and decrease to half of the initial level over time.

Developmental trajectory groups of girls’ depression look different from boys’. In figure 5 and table 4, four groups are identified. Like boys, we observe most of girls (73.5%) experience low initial level and low increase rate (the ‘Low-Increase’ group). 13.3% of girls consist of ‘Increase’ group, which shows constantly increase over 5 years. Different from boys, about 10% of girls show increase across three waves and arrive the peak in the third wave. After that, their depression level decreases. We name this group as ‘One-peak’ group. This group is pretty interesting. Students in Taiwan need to face the pressure of examination for high school entrance around 15 years old (the third wave in current study). Therefore, we observe the ‘One-peak’ group has highest depression at that year; however, after the examination, their depression level

decreases. This provides the hit about the relationship between depression and environment pressure for girls under Taiwan's special educational system. The fourth group contains only 2.4% of girls. These girls show high rate of increase from wave 1 to wave 2 and increase slowly in the later waves. We can see in the fifth wave, these girls show the highest depression level among four trajectory groups. We name this group as 'High-Increase'. Girls in this group may be at high risk in their psychological well-being and need help from social worker or other consulting professions.

The univariate analyses presented above go beyond conventional latent growth model to identify groups in the patterns of developmental trajectories. We show three types of delinquents among boys and two types of delinquents among girls. Boys in our data show fewer groups than what past research shows, but contain similar patterns of trajectories with regard to theory and those empirical findings. The 'High-Rate' and 'Increase' groups among boys correspond to Patterson and Moffitt's developmental theory about adolescent delinquent behavior. We observe there exist a small group of boys starting their delinquent career early and keep relatively high rate of delinquency at age 17. This corresponds to Patterson's 'early starters'. We also observe most of boys show their delinquent behavior in the later waves. This corresponds to Patterson's 'late starters' concept. However, we don't find the same pattern for girls. We only identify possible group for late starters in girl sample. Comparing to boys, girls show very low incidence of delinquent behavior.

Hankin et al. (1998) present a 10-year developmental trend of clinical depression for boys and girls. The age range in their study is from 11 to 21. The result shows a one-peak trajectory both for boys and girls, while girls have higher level of depression than boys. However, they only fit one trajectory model. Our analysis shows four

different groups of depression trajectories for boys and girls. We have already observed the trajectory of girls' depression corresponds to their life course stages.

After presenting the trajectory groups for delinquency and depression, we now turn our analyses to the relationships between the two variables. In the next section, we present the dual trajectory model for delinquent behavior and depression.

Joint trajectory model

Nagin and Tremblay (2001) identify two types of joint trajectory approach. The comorbidity approach models two concurrent variables, while heterotypic continuity models two temporal sequence variables. A good example for heterotypic continuity is the joint trajectory between aggressive behavior in childhood and delinquent behavior in adolescence. Current analysis is a good example for comorbidity model in which we look joint trajectory between delinquent behavior and depression over the same time period.

Joint trajectory model can be treated as a member of latent transition model. In latent transition model, researchers estimate the probability of latent stage at t+1 conditional on latent stage at t (Collins et al., 2002). With the same logic, joint trajectory model estimates the probability of one trajectory group for a variable conditional on the other trajectory group for another variable. One difference between latent transition model and joint trajectory model is that it is no sense to estimate the probability of latent stage at t conditional on latent stage at t+1 in latent transition model. However, in joint trajectory model (the comorbidity model), both conditional probabilities provide useful information. That is, for current example, we concern the

probabilities of delinquent trajectory groups conditional on depression trajectory groups and the probabilities of depression trajectory groups conditional on delinquent trajectory groups. Nagin and Tremblay (2001) provide formulas about the calculation of these probabilities under the joint trajectory model. Proc TRAJ can fit the joint trajectory model and provide estimated probabilities.

Table 5 presents the probabilities of depression trajectory groups conditional on delinquent trajectory groups (pr(depression | delinquency)). When boys are in 'Never' and 'Increase' groups of delinquent behavior, they have higher probability in 'Low-Increase' group of depression than in other depression trajectory groups. For 'High-Rate' delinquent boys, they show high probability in 'Moderate-Constant' and 'Low-Increase' depression trajectory groups. This shows these life-course-persistent delinquents develop their delinquent career accompanying with low to moderate depression. Table 5 also shows girls' situation. Both 'Never' and 'Increase' delinquent trajectory groups have high probability to be in 'Low-Increase' depression trajectory groups.

Table 6 shows the probability of delinquent trajectory groups conditional on depression trajectory groups for boys and girls (pr(delinquency | depression)). Boys in 'Moderate-Constant' depression trajectory group incline to be 'Never' delinquent trajectory group, while for those in 'Low-Increase' depression trajectory group, they tend to be in 'Increase' delinquent trajectory group. Those in 'Increase' depression trajectory group have similar probability in 'Increase' and 'High-Rate' delinquent trajectory groups. Most interestingly, boys in 'Decrease' depression trajectory group tend to be in 'Increase' delinquent trajectory group. This means those decrease in depression level tend to have increase in delinquent behavior over five years. Literature consistently indicates that boys tend to show externalizing behavior when

they experience stress in their life. The co-occurrence of decrease in depression and increase in delinquency provides a vivid evidence of this argument.

Table 6 also shows girls situation. However, the pattern is not as clear as boys'. Except 'Low-Increase', all other depression trajectory group show high probability in 'Increase' delinquent trajectory group. 'Low-Increase' depression trajectory group have similar probability in both delinquent trajectory groups.

From the result of joint trajectory analysis, we observe inconsistency between table 5 and table 6 and boys and girls, also. When boys have specific depression trajectory membership, they show more clear patterns in delinquent trajectory groups, while the membership of delinquent trajectory groups does not help us to classify boys into depression trajectory groups. For girls, both memberships do not provide good classification for each other. Since we fit the comorbidity model, we don't distinguish these two variables in their causal order. However, the inconsistency showed in boys provides some thinking about the co-occurrence of these two variables. Depression membership provides clear classification for boys' delinquent trajectory groups. Table 6 gives us some evidence to say that when studying boys' externalizing behavior, researchers can't leave the development of depression alone. We don't find the same result for girls. This may be because there is small variation in girls' delinquent trajectories. However, it is also possible that the patterns for girls will show in the later years. This requests the continuous collection of the same measures of delinquency and depression over years.

Discussion

The co-occurrence of delinquency and depression gains researchers' attention for intervention reason, since these people suffer most and need the intervention from professions. To understand more about their relationships can provide more information for these practitioners. The systematic testing for the causal relationships between them still shows contradictory results. Although not applicable to testing causal relationships, current study tries to demonstrate the relationships between the two from group-based model. We hope the results provide new information for future studies. We summarize our findings below.

Our univariate analyses show three trajectory groups for boys and two for girls in delinquency. There are four trajectory groups in depression for both boys and girls. The trajectory groups shown in boy sample are consistent with Patterson and Moffitt's theories. For types of delinquency, we at least find a trend for the existence of early and late starters in a non-western data set. However, we only have data in from early to mid-adolescence. Therefore, we should be conservative for and need to test it when data from later waves are available.

Four groups are found in depression trajectories for both boys and girls. To our best knowledge, this is the first study to distinguish types of trajectory groups for depression. Past literature shows a group of people have constant depression level over time (Ge, 1994; Hankin, 1998). Our results find one constant group for boys and there are also low-increase groups both for boys and girls. However, we also find increase groups and decrease groups. We are surprised that in such as short period we can find many different development patterns. This could be that under Taiwan's educational system (high competition in entry examinations), adolescents would

response differentially to this big stressor according to their own characteristics.

Our interlocking models show more clear patterns when delinquent group membership conditioned on depression membership for boys. When boys in increase depression group, they are more likely in increase and high-rate delinquent group, but 0 probability in never group. Low increase group in depression has higher probability in increase delinquent group. We observe some evidence for co-occurrence of delinquency and depression in boys. One interesting finding is that when boys in decrease depression, they incline to be in increase delinquent group. This could be that depressive boys turn to act delinquently and this reduces their psychological tension and depressive moods. However, we don't find any clear co-occurrence for girls. This may be the low variation in girls' delinquency.

Current study does not intend to test the causal relationships between delinquency and depression. We present another newly developed approach to explore the co-occurrence phenomenon. Since we only have early and mid-adolescence data, the results need to be replicated using more waves data into adulthood. Therefore, we can see the life course patterns clearer for these two adolescent problem behaviors.

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Table 1 Zero-order Correlations between Delinquency and Depression across Waves

	Delinquency Wave1	Delinquency Wave2	Delinquency Wave3	Delinquency Wave5	Depression Wave1	Depression Wave2	Depression Wave3	Depression Wave5
Delinquency Wave1	1.000	.264	.088	.126	.270	.154	.138	.072
Delinquency Wave2	.315	1.000	.156	.221	.142	.185	.076	.059
Delinquency Wave3	.371	.310	1.000	.027	.056	-.006	.008	.009
Delinquency Wave5	.218	.108	.266	1.000	.100	.155	.105	.301
Depression Wave1	.207	.059	.100	.142	1.000	.438	.398	.248
Depression Wave2	.100	.124	.145	.145	.463	1.000	.615	.457
Depression Wave3	.223	.170	.180	.135	.400	.533	1.000	.437
Depression Wave5	.109	.037	.082	.323	.195	.319	.446	1.000

Coefficients below diagonal are for boys (N=520); coefficients above diagonal are for girls (N=501)
All coefficients over 0.100 are significant at $p<0.05$

Table 2 Bayesian Information Criterion (BIC) for Model Selection

Model	Delinquency		Depression	
	Boys	Girls	Boys	Girls
One groups	-907.916	-712.027	-839.088	-1138.648
Two groups	-863.019	**-681.812**	-595.639	-899.589
Three groups	**-826.609**	-689.837	-474.478	-851.863
Four groups	-835.983	-692.536	**-446.435**	**-808.733**
Five groups	---	---	-502.478	-818.058

Bold means the selected model

Table 3 Estimated Parameters in Group-Based Model: Boys Model
(Estimated group percentage in parenthesis)

N=520	Parameter	Coefficients	Standard Error
Delinquency			
Never (25.5%)	Intercept	-2.700	339564553
Increase (61.5%)	Intercept	-0.140*	0.033
	Slope	-2.332*	0.329
	Quadratic	0.071*	0.008
High rate (12.9%)	Intercept	0108*	0.039
	Slope	0.036*	0.014
Depression			
Moderate-Constant (13.8%)	Intercept	1.529*	0.048
	Slope	0.011	0.020
Low-Increase (78.6%)	Intercept	1.119*	0.011
	Slope	0.024*	0.005
Increase (4.8%)	Intercept	1.319*	0.049
	Slope	0.270*	0.027
Decrease (2.7%)	Intercept	2.848*	0.092
	Slope	-0.747*	0.106
	Quadratic	0.103*	0.023

* $p<0.05$

Table 4 Estimated Parameters in Group-Based Model: Girls Model
(Estimated group percentage in parenthesis)

N=501	Parameter	Coefficients	Standard Error
Delinquency			
Never (50.2%)	Intercept	-0.583*	0.108
	Slope	-1.408	133.396
Increase (49.8%)	Intercept	-0.172*	0.033
	Slope	-0.106*	0.037
	Quadratic	0.036*	0.008
Depression			
Increase (13.3%)	Intercept	1.345*	0.037
	Slope	0.191*	0.017
Low-Increase (73.5%)	Intercept	1.188*	0.013
	Slope	0.033*	0.006
One-Peak (10.7%)	Intercept	1.776*	0.058
	Slope	0.341*	0.064
	Quadratic	-0.100*	0.014
High-Increase (2.4%)	Intercept	1.759*	0.086
	Slope	0.669*	0.110
	Quadratic	-0.093*	0.025

* $p<0.05$

Table 5 Depression Trajectory Group Probabilities Conditional on Delinquency Trajectory Group

Boys		Depression			
		Moderate -Constant	Low -Increase	Increase	Decrease
Delinquency	Never	0.009	0.989	0.002	0.000
	Increase	0.126	0.785	0.058	0.031
	High-Rate	0.455	0.392	0.091	0.062

Girls		Depression			
		Increase	Low -Increase	One-Peak	High -Increase
Delinquency	Never	0.079	0.866	0.052	0.002
	Increase	0.187	0.603	0.163	0.047

Table 6 Delinquent Trajectory Group Probabilities Conditional on Depression Trajectory Group

Boys		Delinquency		
		Never	Increase	High-Rate
Depression	Moderate-Constant	0.438	0.314	0.248
	Low-Increase	0.04	0.774	0.186
	Increase	0	0.522	0.478
	Decrease	0.052	0.896	0.052

Girls		Delinquency	
		Never	Increase
Depression	Increase	0.299	0.701
	Low-Increase	0.592	0.408
	One-Peak	0.245	0.755
	High-Increase	0.042	0.958

Figure 1 Selected Trajectories of Delinquency and Depression

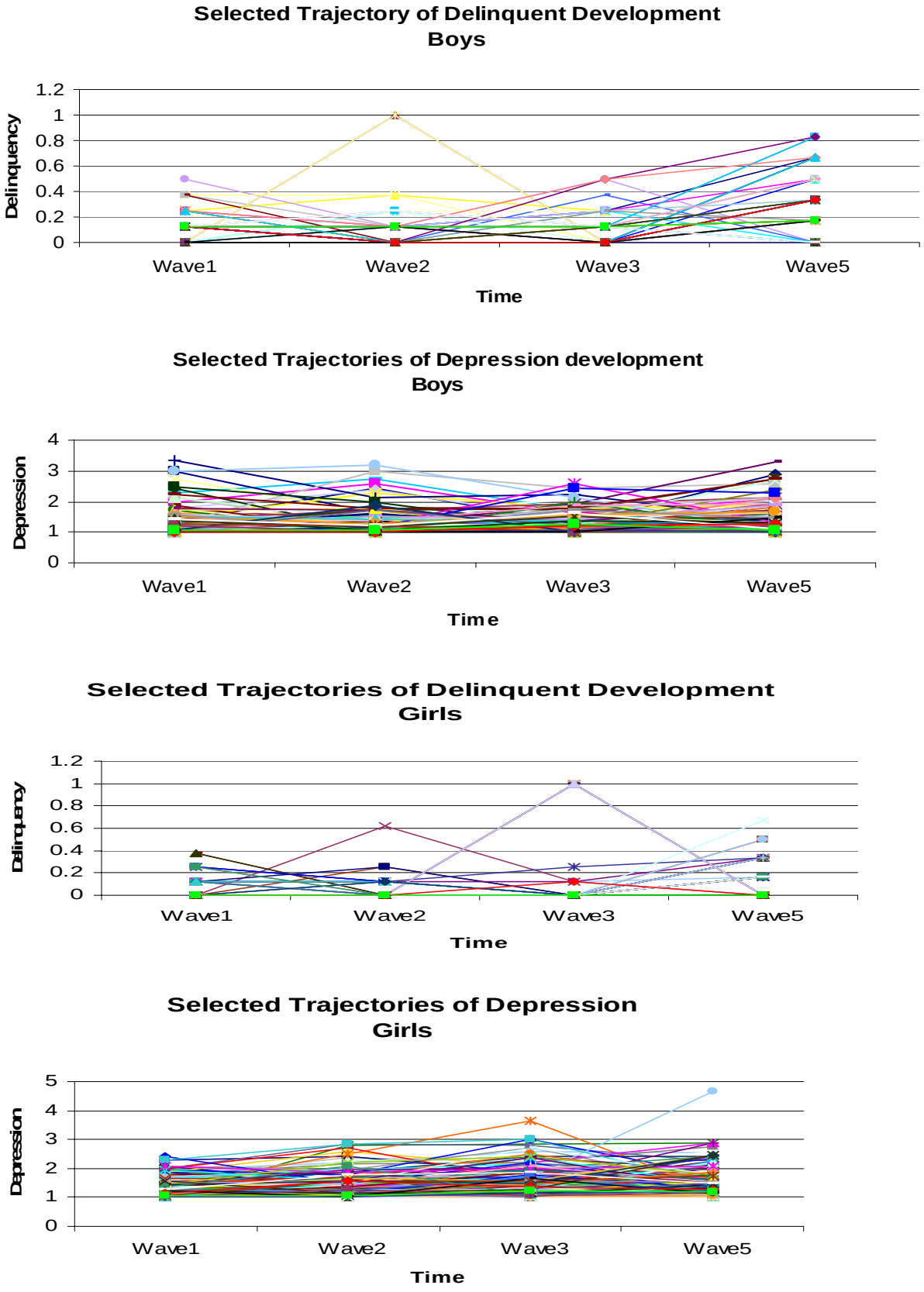

Figure 2 Trajectory Groups of Delinquency
Boys

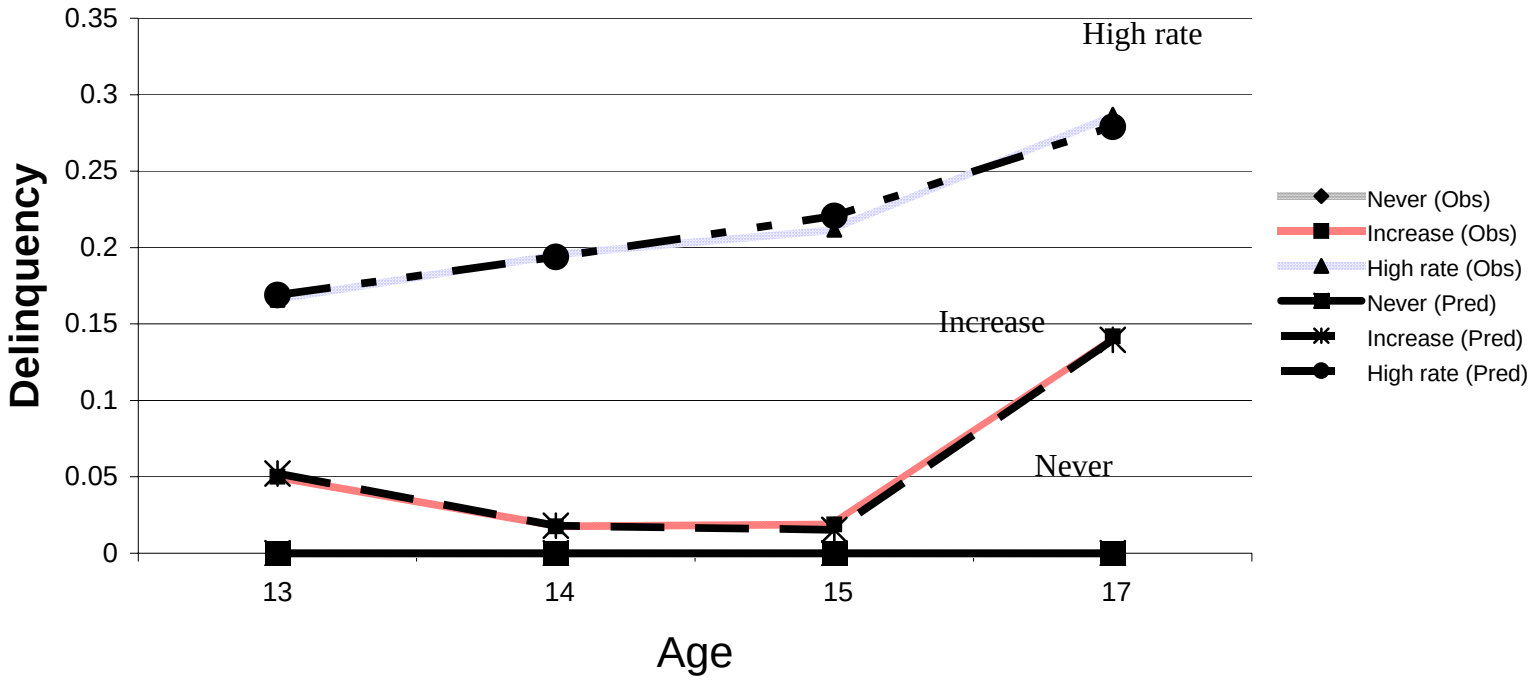

Figure 3 Trajectory Groups of Depression
Boys

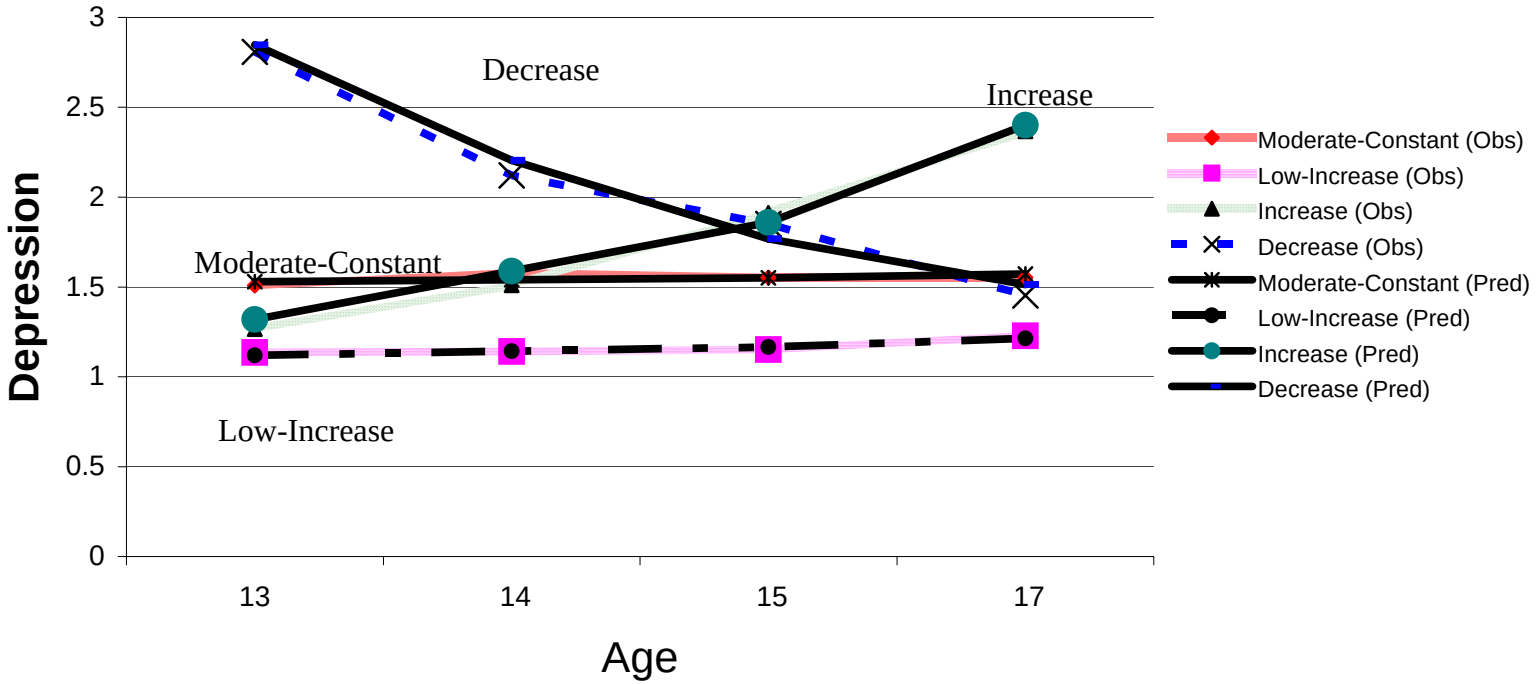

Figure 4 Trajectory Groups of Delinquency Girls

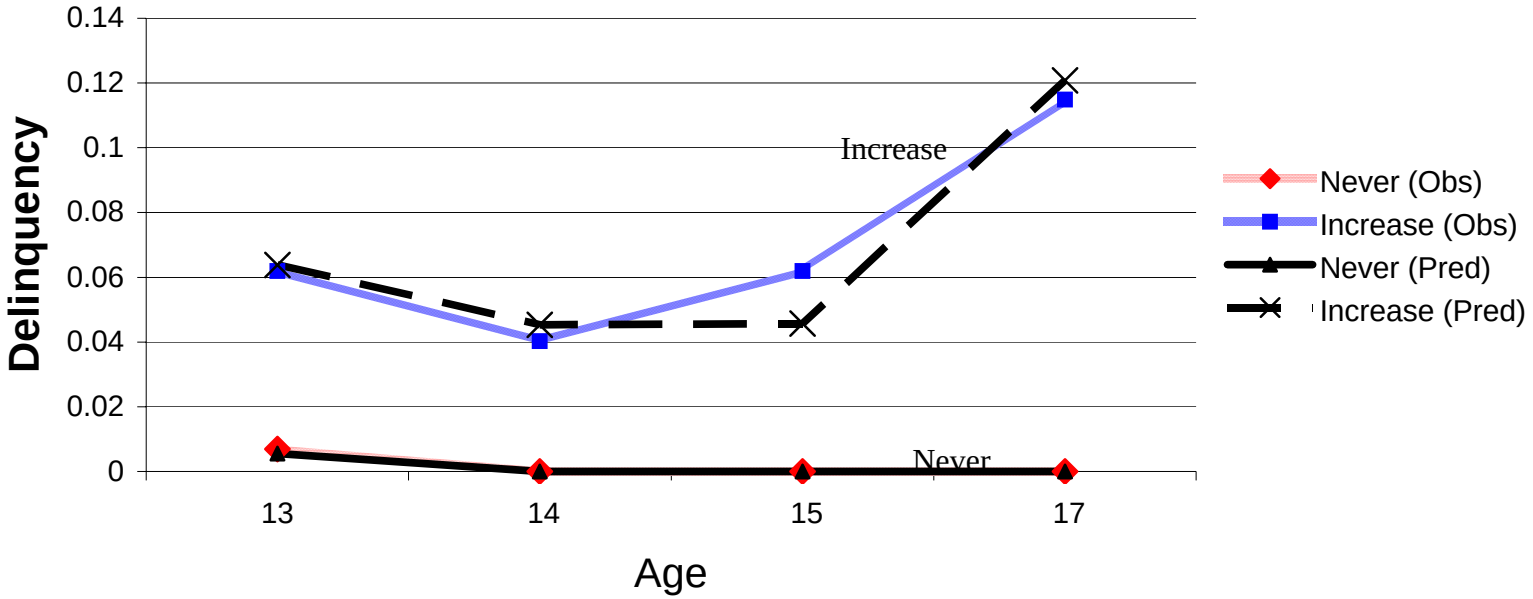

Figure 5 Trajectory Groups of Depression Girls